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RESEARCH BULLETIN

A DEVELOPMENTAL STUDY OF ATTENTION: A MULTIVARIATE APPROACH

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Abstract

A factor analytic technique was applied to the attentional data from a visual episode presented longitudinally at 6, 13, 25 and 44 months of age. Two factors were identified: an orienting factor, consisting of fixation, cardiac deceleration, and cessation of activity, and an affect factor, consisting of smiling, vocalizing, and cardiac deceleration.

A Developmental Study of Attention: A Multivariate Approach[1]

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Many different responses have been employed in measuring infant attention in recent years. Both behavioral observations and physiological changes have been called upon. Among the measures used are looking time (Fantz, 1963; Friedman, Nagy & Carpenter, 1970; Lewis, Kagan & Kalafat, 1966), changes in ongoing activity and movement (Engen, Lipsitt & Kaye, 1963; Lewis & Wilson, 1970), sucking behavior (Haith, Kessen & Collins, 1969; Kaye, 1966), heart rate deceleration (Graham & Clifton, 1966; Lacey, 1967), and respiratory changes (Engen et al., 1963; Steinschneider, 1968). The majority of these studies have been based upon one or at most two measures. One exception is a study of complexity and incongruity in which five measures were recorded: looking time, heart rate, activity, vocalizing and smiling (Lewis, Wilson & Baumel, 1971). With so many measures related to attention, it seems possible that the interrelationships among them might be at least as relevant to the study of infant attention as the measures themselves.

A second reason for using multiple response measures is that responses change meaning as the infant develops. As Lewis (1967) has stressed in recent years, a single response studied at a single age, or even over several ages, can be misleading. Lewis found that an infant who cries in response to frustration at two months does not cry in response to frustration at one year; rather, he actively attempts to overcome the frustration. On the other hand, the child who shows little reaction to frustration at two months tends to cry in the face of frustration at a year. Thus, crying changes its meaning—at the early age, it is an active response, but by a year, it has become a passive response; the active response has taken a new form. Only an approach which uses multiple responses over time can provide this information. If responses change meaning, or if the responses in the service of a psychological structure undergo changes, then it is necessary to have a variety of responses in order to observe such changes.

At least two types of multivariate approaches are possible. The first is the intercorrelational technique in which all responses at each age are correlated with all responses at each other age. A typical result: two measures of attention at different ages, heart rate deceleration and looking time, are not consistent over age. However, the across-age correlations indicate that heart rate deceleration at six months and looking at one year are strongly related. From this, the investigator may infer that at six months heart rate deceleration is the better indicator of attention, perhaps due to the lower mobility at the early age, which affects the flexibility of the looking response. Further, he infers that the two responses change meaning in the second half of the first year, and by one year, looking time is the better indicator of attention, perhaps due to increased activity which in turn affects heart rate.

A more sophisticated approach is the factor analytic technique in which clusters of highly intercorrelated measures are identified. The clusters are then assumed to represent some underlying psychological structure. Thus, the clusters, rather than single measures, become the focus of across-age comparisons. One might argue that the clusters themselves do not change their meaning over age--just the particular responses which fall within a cluster might vary.[2] Alternatively, the items within a cluster might be stable, but their loadings might change over age.

The second approach, using a principal component analysis, was applied to attentional data gathered in a longitudinal study of children 6 to 44 months of age.

Method

Subjects. The subjects were 32 boys and 32 girls, seen longitudinally at 6, 13, 25 and 44 months of age. The socioeconomic level was fairly heterogeneous, though skewed slightly toward the upper end of the scale.

Procedure. The children were seated in an infant seat or junior chair in a uniform grey room, 5' x 5'. Visual stimuli were presented at eye level by rear screen projection 2 1/2' from the child. The measures recorded were total looking time, number of discrete looks, heart rate deceleration, activity, smiling and vocalizing, using the techniques developed by Lewis (see Lewis et al., 1971). Briefly, all measures except heart rate were recorded by observers unseen by the child. The observers pushed a button connected to an event recorder when a behavior occurred and held it for the duration of the behavior. Heart rate change was recorded using electrodes attached to a polygraph. Smiling was not recorded at 6 and 13 months, and activity was not recorded at 44 months.

The visual stimuli varied over age in complexity and interest in an attempt to maintain a fairly consistent level of attention over age. However, in general they could be classified as social (having faces) and nonsocial. Except at 44 months, all pictures were achromatic, and were presented for 12 seconds with a 12-second intertrial interval. The order of presentation was randomized within each complete series of pictures, e.g., no stimulus was presented for the second time until all had been presented once.

Insert Table 1 about here

Table 1 lists the pictures used at each age. At 6 months and 13 months the sample was divided in half, with different stimuli shown to the two halves of the sample on a slightly different schedule (referred to as samples 1 and 2 for convenience).

At 6 months for both samples the series included six pictures. For the first sample, the six pictures were shown randomly for a total of five trials each. For the second sample, a schematic drawing of a face was substituted for the panda face, and each picture was presented six times.

At 13 months the picture series included the same pictures used for the second sample at 6 months, plus, for half the sample, six additional pictures. For the first sample, each of the six pictures was presented six times. For the second sample, each of the six 6-month pictures was shown for three trials each. After all six pictures had been presented three times, the six new stimuli were introduced and each was shown a total of three times. Thus, both samples received a total of 36 trials, but the second sample was shown different stimuli for the last 18 trials. No social-nonsocial distinction was made for the six new stimuli.

At 25 months both samples received the same picture series. The series consisted of 12 stimuli (all social), each presented three times. Five of the pictures had been used at 13 months.

At 44 months four sets of two pictures were used, two social sets and two nonsocial. For each set one picture was presented for six consecutive trials (standard), followed by the other picture for the seventh trial (violation). The series thus consisted of 28 trials, each 30 seconds in length with a 30-second intertrial interval.

Results and Discussion

In a principal component analysis, the number of components, or factors, is determined by the number of measures included in the analysis: if there are six measures, the analysis computes six components, ordered such that the first component accounts for the greatest variance. Each component consists of all the measures, appropriately weighted to maximize the variance accounted for by that component. While all the measures have a "value" or loading on each component, some measures are loaded quite heavily while others are close to zero. There are several ways of determining which loadings are strong enough to be meaningful. The simplest and most straightforward method is to treat the loadings as correlation coefficients, with N being the number of subjects used in the component analysis. This approach, using the .05 level of significance, was used below.

At all four ages, the first two components described the data adequately--in all cases, all measures showed significant loadings in at least one of the two components, and the two components together accounted for well over half the total variance. The results are shown in Table 2. The two components at 44 months account for almost equal parts of the total variance, and have been reversed for a more meaningful presentation of the data. That is, the first component (accounting for the most variance) has been presented as the second and the second as the first. The blanks in the table indicate that these measures were not recorded at these ages.

Insert Table 2 about here

For all ages, the first component accounted for 31% to 34% of the total variance, well over the 20% expected (17% at 25 months) if all the components accounted equally for the variance. Moreover, the pattern of significant loadings was quite similar over age. At all ages, looking time showed the strongest loading. For three ages (excluding 13 months), much looking was associated with decreases in heart rate. Moreover, the relationship was stronger for the two older ages than for the younger ones. In addition, for the three ages at which activity was recorded, much looking was associated with little activity.

The other measures were less consistent in the first component over age. Number of discrete looks was loaded positively at 6 and 13 months, was not significant at 25 months, and was negatively loaded at 44 months. Thus, this measure appears to change meaning over age in relation to the other variables. At the earlier ages, many discrete looks is related to much looking, decreases in heart rate and little activity--high attention--while by 44 months many looks is related to little overall looking, little deceleration and much activity--low attention. Finally, much looking was related to little vocalizing at 6 and 25 months, and to much vocalizing at 44 months. Smiling was not included in the first component at any age.

The second component together with the first accounted for 56% to 64% of the total variance, well above the 40% expected (34% at 25 months) if the variance was distributed evenly over all the components. This component was more variable over age than the first. All the measures were significantly loaded in this component at one age or another. However, the most consistent loadings were for the number of looks, vocalizing and smiling, with many looks related to much vocalizing and much smiling. In addition, heart rate was loaded significantly at 6 and 13 months, such that many looks were related to decreases in heart rate. This result is interesting in view of the fact that heart rate deceleration was included in the first component particularly strongly at the two older ages. Thus, heart rate deceleration shifts its association from the second component at the early ages to the first component at the later ages. Finally, activity was significantly weighted at both 6 and 13 months, but in opposite directions.[3]

Further analysis was necessary to determine if the components, while similar in pattern over age, were actually representing the same underlying structure over age. The coefficient of concordance was computed for each component using the four measures which were available at all four ages (total fixation, number of fixations, cardiac deceleration, and vocalization). The coefficient was significant at the .01 level of probability for both components (first component, $W = .775$; second component, $W = .675$). Thus, the structures represented by the two components appear to be the same over age.

While the structures themselves are stable over age, it does not necessarily follow that a given child's responses in the service of the structure remain the same over age. To test for individual consistency, component scores were computed for each child at each age: the child's score on each measure was multiplied by the appropriate component loading, and the sum of the products obtained. Thus, each child received two component scores, proportionately weighted for the first and second components.

Only the first component was stable over age, and the consistency suggests a simplex pattern--i.e., the components were related only from one age to the next. Only the 13-month to 25-month relationship was significant for the total group ($r = .38$, $p < .01$). The consistency was greater for the girls. For girls, not only did 13 months predict 25 months ($r = .40$, $p < .05$), but also 25 months predicted 44 months ($r = .40$, $p < .05$). The one long-term relationship which reached significance was for the first component for the boys: 6

months predicted 44 months (r = .43, $p < .05$). The remainder of the correlations were generally nonsignificant.

It is somewhat surprising that the component scores did not show greater consistency over age. However, much of the variability is probably accounted for by the variation in the measures recorded and stimuli used at each age, and thus in the data on which the components were based. Greater consistency would probably be found if the measures were the same at each age.

It is interesting that in spite of the wide variation in the stimuli, the two components show many similarities over age. The two components represent quite different patterns of behavior, both relating to attention. While all the measures except smiling are included in both components at one age or another, a consistent pattern emerges for each component over age. The first component is consistently characterized by much looking, decreases in heart rate, particularly at the older ages, and little activity. Thus, this component includes those responses involved in receptor and body orientation, and might be said to represent an orienting factor.

In contrast, the second component generally represents many discrete looks, much vocalizing, much smiling, and decreases in heart rate at the two younger ages. Thus, it appears that the component includes an affect measure--vocalizing or smiling--for all but 6 months. The component, then, might be interpreted as representing an affect factor of attention, and as such adds a new dimension to attention beyond the orienting response.

These interpretations are supported by further analysis in which the principal components were determined for the social and nonsocial data separately. The 25-month data were not included in this analysis as all the stimuli were social.

Insert Table 3 about here

The analysis was based on the assumption that social stimuli are more apt to elicit affect responses, and that this would influence the component patterns. The results, as seen in Table 3, consistently show the orienting component to be stronger--that is, account for more variance--for the nonsocial stimuli, when the affectual responses can be presumed to be at a minimum. Moreover, the affect component was consistently stronger for the social stimuli, when the affect responses can be presumed to be greater. Finally, at 44 months, the orienting and affect components were reversed, with the affect component accounting for greater variance. However, in the social and nonsocial analyses, the components were reversed only for the social pictures; that is, the affect component accounted for more variance (44%) than the orienting component (28%) only for the social pictures, when the affect responses are expected to be greater. For the nonsocial pictures, the components were in the expected order, with orienting accounting for the greater variance (39% as against 32% for affect). While these results are not overwhelming in their magnitude, certainly their consistency over age must lend some credence to their validity.

Thus, two components of attention have been identified, and similarities over age illustrated. The question arises, however, why two components are necessary to describe adequately a child's response to a visual stimulus. Closer analysis of the process of attending provides an answer. Imagine the sequence of responses when a child looks at his mother's face. The initial reaction is one of orientation--intense looking, depression of heart rate, inhibition of ongoing behaviors such as activity, smiling and vocalizing--in fact, all the responses which appear in the first component, or orienting factor. After recognition takes place, the affective element of the stimulus--

i.e., face, and especially, mother's face--comes into play and evokes affectual responses in the child. Thus, the child's response to his mother's face is in fact two clusters of responses: the initial orienting responses and the subsequent affectual responses.

The argument is made, then, for a multiple-response approach to the study of attention. A multivariate approach is necessary for two reasons. First, responses change meaning over age--many discrete looks at the younger ages was indicative of high attention and interest, while at the later ages, many looks was representative of low attention and boredom. This kind of knowledge is gained only when one response is compared to other responses. Second, at least two types of responses are called into play in the process of attending--orienting and affect. Obviously only a multiple-response approach will yield this information. From this it is clear that a description of attention based upon a single response measure is at best inadequate, and at worst superficial.

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Footnotes

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[2]This, of course, argues for an individual differences model rather than a developmental one. That is, an individual difference model suggests that changes occur not in the structure, but only in the responses in its service (this change could be maturational). A developmental model suggests that changes occur in the structure itself. At this point it is too early to separate these two positions for this case of attending behavior.

[3]The components were rotated using a varimax procedure and the results were substantially the same. In fact, except for the 6-month data, they were nearly identical. For this reason we have chosen to use the unrotated components.

Table 1

List of Pictures Used at Each Age

Age	Social	Nonsocial
6 Months 1st Sample	Female Face Male Face Panda Face	Bull's-eye Checkerboard Baby Bottle
6 Months 2nd Sample & 13 Months 1st Sample	Female Face Male Face Schematic Drawing	Bull's-eye Checkerboard Baby Bottle
13 Months 2nd Sample	Same as 13 months, 1st sample	Same as 13 months, 1st sample
	Man and Woman Seated Woman Woman and Baby	Cyclops Upside-Down Silhouette (nonsense) 3-headed Man
25 Months	Seated Female Male and Female Female and Baby Seated Male Family Baby Body without Head 3-headed Man Cyclops Man without Ears Teacups for Ears Head and Body Severed	
44 Months	Set A: Family Group in color (Violation: family group in black & white) Set C: Boy & Dog (Violation: Boy and Goat)	Set B: Squares with one circle (Violation: circles with one square) Set D: 20 curved lines (Violation: 20 straight lines)

Table 2

The First Two Principal Components at each Age and the Percentage of the Variance Accounted For

Measure	Age			
	6 Months	15 Months	25 Months	44 Months[a]
First Component				
Total Looking Time	.79*	.85*	[illegible]	.76*
Number of Looks	.44*	.74*	[illegible]	[illegible]
Heart Rate Deceleration	.55*	-.12	.56*	.82*
Activity	[illegible]	-.50*	-.84*	-
Vocalizing	-.70*	-.25	-.44*	.50*
Smiling	-	-	-.08	[illegible]
Percentage of Variance	34%	32%	[illegible]	31%
Second Component				
Total Looking Time	.05	.18	.19	[illegible]
Number of Looks	.81*	-.06	[illegible]	.57*
Heart Rate Deceleration	.29*	.80*	-.05	.14
Activity	.76*	-.29*	-.04	-
Vocalizing	.15	.69*	.58*	.74*
Smiling	-	-	.81*	.78*
Percentage of Variance	27%	25%	24%	33%

[a]The 44-month components are reversed for a more meaningful presentation of the data.

*Significant loadings.

Table 3

Percentage Variance Accounted for by First Two Components

as a Function of Social and Nonsocial Stimuli

	6 Months		13 Months		44 Months	
	Orienting Component	Affect Component	Orienting Component	Affect Component	Orienting Component	Affect Component
Stimuli						
Social	35	29	33	30	28	[illegible]
Nonsocial	45	24	34	26	32	39